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EARLY GROWTH IN WEIGHT OF KEMP'S RIDLEY SEA TURTLES (*LEPIDOCHELYS KEMPII*) IN CAPTIVITY

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ABSTRACT Growth in individual weight (**w**, kg) of Kemp's ridley sea turtles (*Lepidochelys kempii*) in captivity was described for 15 year-classes (1978-1992) of turtles between ages (**t**) 0.17 to 1.22 yr, using *ln*-linear regression: $\ln w = \ln c + dt^{1/2}$, where $\ln c$ is the intercept and **d** is the slope (growth rate index). There was significant ($P < 0.001$) heterogeneity in **d** among year-classes, with slowest growth ($d = 3.798$) exhibited by the 1983 year-class and fastest growth ($d = 6.929$) by the 1985 year-class, but there was no significant trend in **d** ($P = 0.307$) over year-classes. The variance of residuals from regression, s^2_{reg}, ranged from 0.2032 for the 1978 year-class to 0.0075 for the 1992 year-class, and showed a significant ($P = 0.0001$) logarithmic decrease over the year-classes. This decline in variation among individuals was probably due to a a shift toward sex ratios dominated by one sex (females), improvements in rearing facilities, year-around control of seawater temperature which reduced disease incidence, improved diet, and reduced feeding levels. The relationship between **w** and **scl** (straight carapace length) was also described.

Introduction

The Kemp's ridley (*Lepidochelys kempii*) head-start experiment was initiated in 1978 as part of a Mexico-U.S. recovery program for this seriously endangered species (Klima and McVey 1982; Woody 1986, 1989). Its main purposes were to increase survival by captive-rearing the turtles during the critical first year of life, and to establish a nesting colony on Padre Island, Texas (Figure 1) through imprinting (Klima and McVey 1982; Woody 1986, 1989; Shaver 1989, 1990). Secondarily, it offered opportunities to develop husbandry practices (Fontaine et al. 1985, 1989; Leong et al. 1989), and to study growth and survival in captivity and in the Gulf of Mexico, following reintroduction (Caillouet and Koi 1985; Caillouet et al. 1986, 1989, 1993, 1995a, b, c).

Of the 25,676 hatchlings received alive from the 1978-1992 year-classes, 22,255 (86.7%) were successfully reared, tagged and released into the Gulf of Mexico at sizes comparable to late-pelagic or early post-pelagic stage in wild Kemp's ridleys (Ogren 1989). Captive-rearing ended with release of the 1992 year-class, but the search for head-started Kemp's ridleys in the wild continued (Byles 1993; Williams 1993; Eckert et al. 1994). In May 1996, the first two documented nestings by head-started Kemp's ridleys occurred at Padre Island (Shaver 1996). One nester was from the 1983 year-class and the other from the 1986 year-class.

This paper describes and summarizes growth of the 1978-1992 year-classes of Kemp's ridleys in captivity up to 1.22 yr of age, based on an exponential model.

Materials and Methods

Hatchlings were obtained from eggs collected at the species' primary nesting beach near Rancho Nuevo, Tamaulipas, Mexico (Figure 1; Caillouet 1995b). Most hatchlings came from eggs placed in incubation boxes containing sand from the National Park Service's Padre Island National Seashore (PINS) near Corpus Christi, Texas (Figure 1), and transported to PINS for incubation, hatching and "imprinting" (Burchfield and Foley 1989; Shaver 1989, 1990). However, some were "imprinted" at Rancho Nuevo, after they emerged from eggs placed in artificially constructed nests within protected corrals (Caillouet 1995b). Hatchlings from PINS or Rancho Nuevo were transferred to the National Marine Fisheries Service's Galveston Laboratory for captive-rearing.

Individual weights (**w**, kg) were measured on samples of turtles at varying intervals during captive-rearing of year-classes 1978-1992, so that feeding rate could be controlled as a percentage of average body weight (Fontaine et al. 1985, 1989; Caillouet et al. 1986, 1989). Straight carapace lengths (**scl**, cm) were measured less frequently (Fontaine et al. 1985, 1989). Sample size for **w** at age (**t**, yr) varied from 1 to 1,774 turtles.

We calculated the variance, s^2, and mean, $\bar{w}$, of all samples containing 25 or more turtles. The slope of the linear regression of $\ln s^2$ on $\ln \bar{w}$ was 2.014 for turtles 0.17-1.22 yr (2-14.6 mo) old, suggesting that the distribution of **w** at **t** was *ln*-normal within that range of **t** (Figure 2; see Taylor 1961). Turtles less than 0.17 yr old were excluded in fitting the linear regression, because the scatter of points

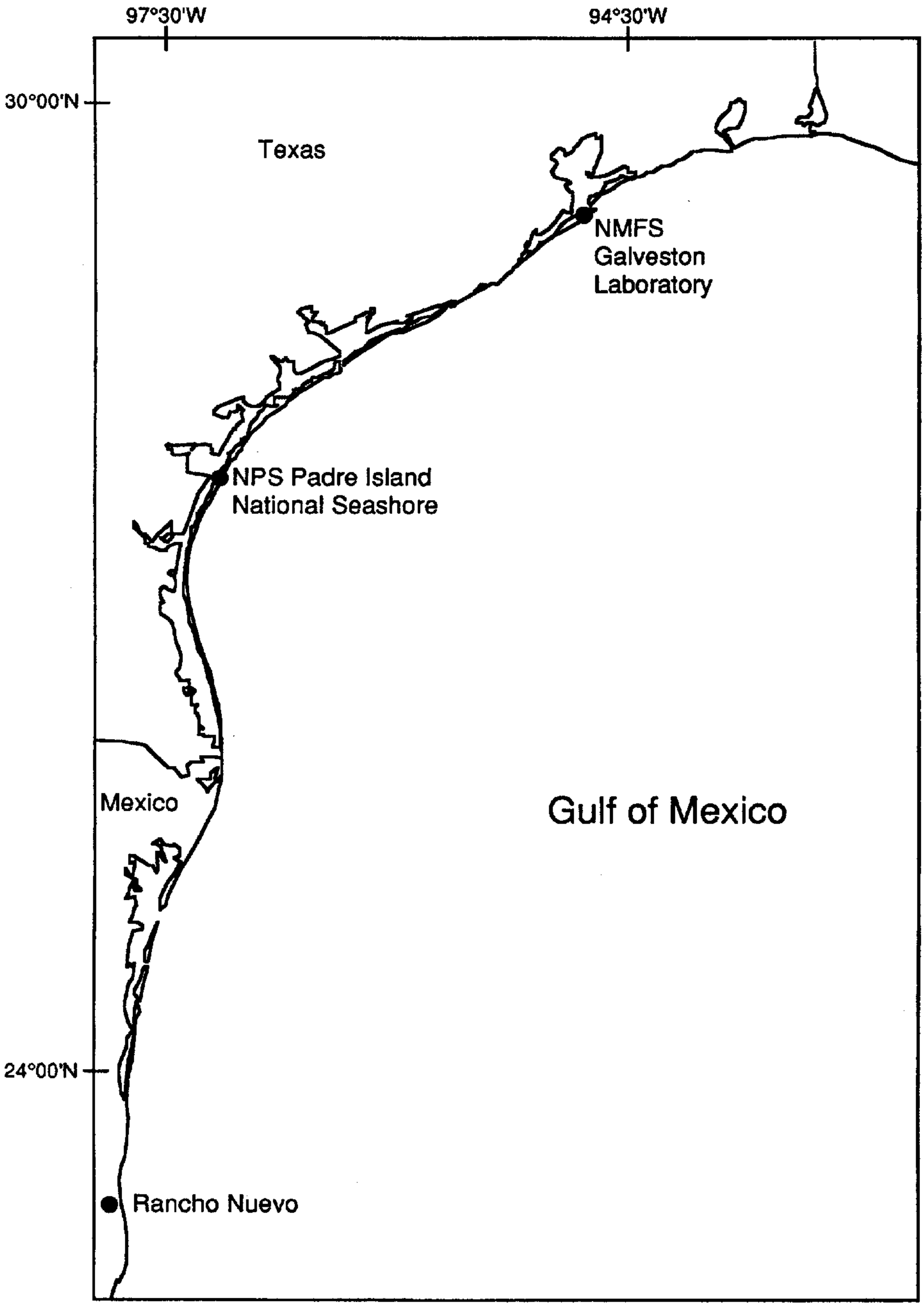

Figure 1. Location of the National Marine Fisheries Service (NMFS) Galveston Laboratory, National Park Service (NPS) Padre Island National Seashore and Rancho Nuevo nesting beach.

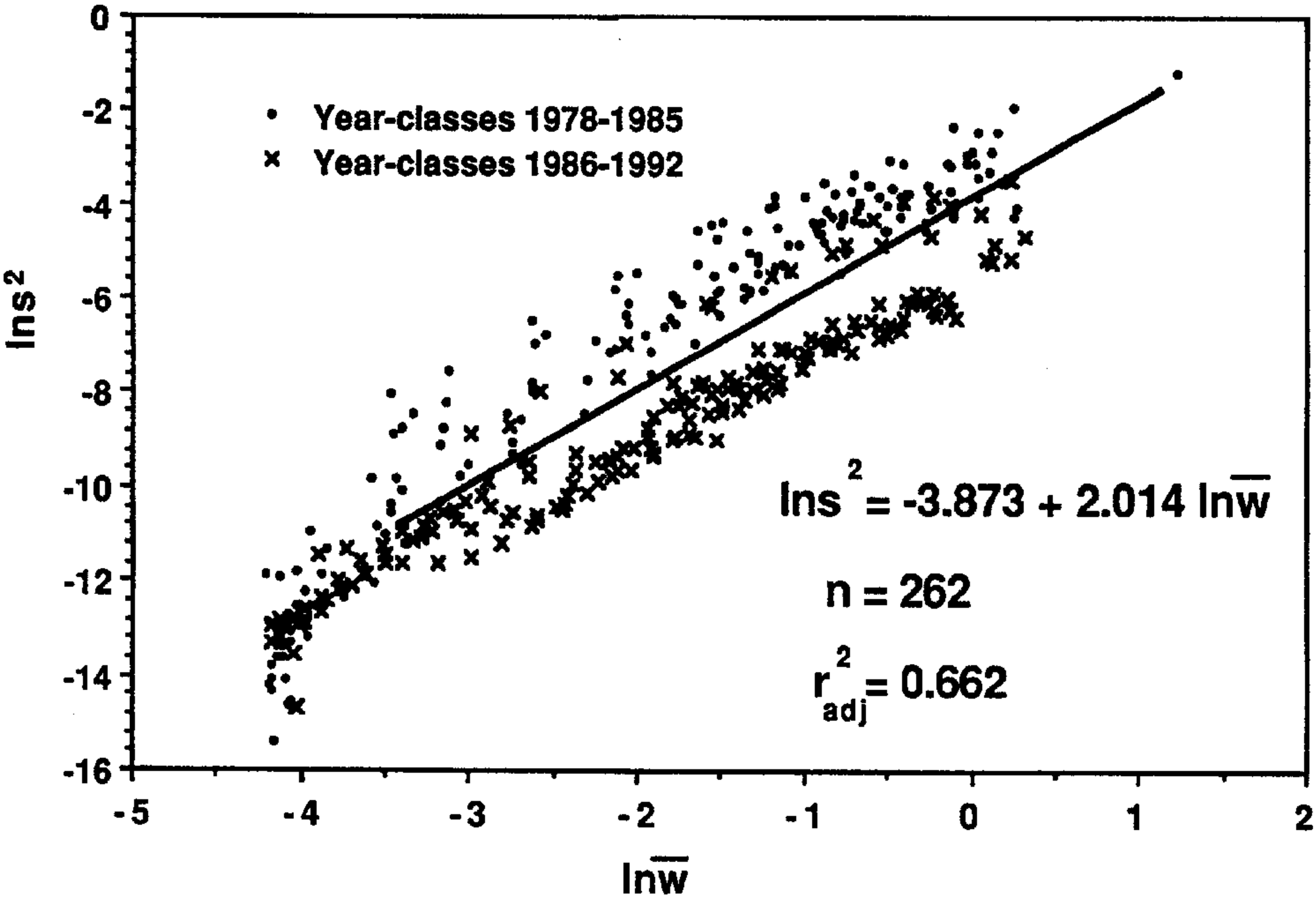

Figure 2. Relationship between natural logarithms of variances and arithmetic means (lns^2 and $ln\bar{w}$, respectively) of weight (w, kg) in samples of captive-reared Kemp's ridleys (*Lepidochelys kempii*) containing 25 or more turtles at age t. The straight line was fitted to 262 data points representing turtles 0.17 to 1.22 yr of age, but the scatter also included 86 data points for turtles < 0.17 yr old.

curved downward in the left portion of the lns^2 vs $ln\bar{w}$ plot (Figure 2). We plotted the data based on two groups of year-classes, with dots representing the 1978-1985 year-classes and x's representing the 1986-1992 year-classes. The latter year-classes were an estimated 83.0-99.6% female, whereas the former were 28.8-53.8% female, except for year-class 1981 in which the inadequate sample of four turtles contained only females (Caillouet 1995a).

Growth of turtles, between ages 0.17 and 1.22 yr, in each year-class and for combined year-classes, was described by an exponential model fitted by *ln*-linear regression (see Caillouet et al. 1986, 1989), as follows:

$$\mathbf{ln w = ln c + d t^{1/2}} \quad (1)$$

where

ln c = intercept, and

d = slope (growth rate index)

In addition to the *ln*-transformation of **w**, a square root transformation of **t** was necessary to linearize the relationship (see Box and Tidwell 1962; Caillouet et al. 1986, 1989).

The *ln*-linear relationship between **w** and **scl** was determined for combined year-classes, as:

$$\mathbf{ln w = ln a + b\ ln scl} \quad (2)$$

where

ln a = intercept, and

b = slope

Data from turtles 0.01 yr $\leq$ **t** $\leq$ 1.22 yr were used in fitting equation 2.

Goodness of fit for all *ln*-linear regressions was measured by the adjusted coefficient of determination, r^2_{adj} calculated as follows:

$$\mathbf{r^2_{adj} = 1 - [(n - 1)(1 - r^2)/(n - 2)]}$$

where

n = number of observations

$\mathbf{r^2}$ = coefficient of determination

Estimates of *ln*w obtained from equation 1 were detransformed to w_{adj}, which is the estimated **w** adjusted for *ln*-normal bias (see Sprugel 1983) as follows:

$$\mathbf{w_{adj} = EXP\ [ln w + (s^2_{reg}/2)]} \quad (3)$$

RESULTS

Equation 1 fit the data for each year-class ($647 \leq n \leq 7{,}708$) well as shown by high coefficients of determination, r^2_{adj}, ranging from 0.726 to 0.991 for the first and last year-classes, respectively (Table 1). The same was true (r^2_{adj} = 0.798, n = 65,210) for combined year-classes, but r^2_{adj} was lower for combined year-classes than for individual year-classes due to variation among year-classes. The mean square deviation from regression, s^2_{reg}, ranged from 0.2032 to 0.0075 for the 1978 and 1992 year-classes, respectively (Table 1), showing a significant (P = 0.0001) logarithmic decrease over the year-classes (Figure 3).

There was significant ($P < 0.001$) heterogeneity in the slope, d, of equation 1 among year-classes, with slowest growth (d = 3.798) in the 1983 year-class and fastest growth (d = 6.929) in the 1985 year-class (Table 1). However, there was no significant trend in d (P = 0.307) over year-classes. Equation 1 parameter estimates (Table 1) were applied to estimate w_{adj} at 1 and 1.22 yr, for each year-

TABLE 1

Regression statistics for the *ln*-linear model (equation 1) of growth in individual weight (w, kg) of head-started Kemp's ridleys (*Lepidochelys kempii*) between ages 0.17 ≤ to ≤ 1.22 yr in captivity, for each year-class and combined year-classes.

Year-class	n	Intercept, *Inc*	Slope, d	Mean square deviation from regression, s^2_{reg}	Adjusted coefficient of determination, r^2_{adj}
1978	6074	-4.757	4.763	0.2032	0.726
1979	6442	-4.700	4.944	0.1046	0.867
1980	4759	-4.306	4.684	0.0760	0.859
1981	7708	-5.335	5.160	0.0569	0.938
1982	5228	-4.848	4.953	0.1069	0.861
1983	647	-4.415	3.798	0.0786	0.786
1984	5714	-4.667	4.396	0.0994	0.832
1985	6307	-6.040	6.929	0.0694	0.937
1986	4539	-4.302	4.896	0.0542	0.892
1987	4290	-5.705	6.508	0.0476	0.964
1988	2609	-5.225	5.318	0.0108	0.985
1989	3772	-5.183	4.733	0.0179	0.976
1990	2624	-5.538	5.468	0.0121	0.986
1991	2373	-4.679	4.199	0.0076	0.980
1992	2124	-6.066	6.261	0.0075	0.991
Combined	65,210	-5.024	5.167	0.1839	0.798

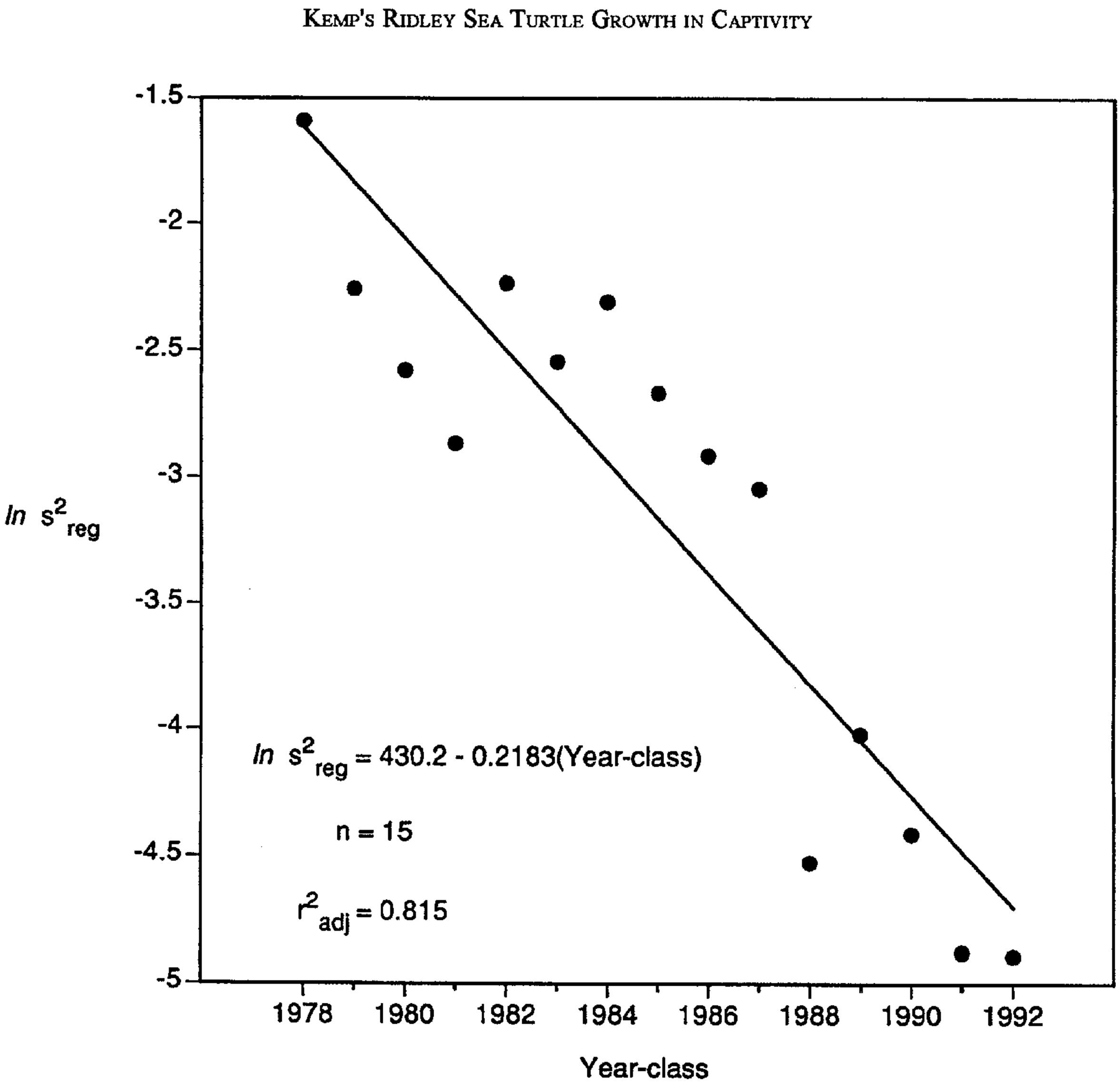

Figure 3. Relationship between lns^2_{reg} for the *ln*-linear growth model (equation 1) and year-class (1978-1992) in captiv reared Kemp's ridleys (*Lepidochelys kempii*) 0.17 to 1.22 yr of age (t) (see Table 1).

class and combined year-classes (Table 2).

The *ln*-linear **w-scl** model (equation 2) applied to the subset of data in which both **w** and **scl** were measured (**n** = 53,317) fit the data well ($\mathbf{r^2_{adj}} = 0.994$) for combined year-classes. The intercept (*ln***a**) and slope (**b**) were -8.438 and 2.920, respectively. We substituted $\mathbf{w_{adj}}$ estimated from equation 1 for **w** in equation 2, and solved for **scl** to obtain **scl** at 1 and 1.22 yr (Table 2).

DISCUSSION

Exponential growth curves can be generated for each year-class and year-classes combined by detransformation of *ln***w** estimated from linear regression results in Table 1, with an adjustment for bias (equation 3) based on $\mathbf{s^2_{reg}}$ obtained in fitting equation 1. An exponential **w-scl** curve can be derived by detransformation of *ln***w** estimated from equation 2, which also requires an adjustment for bias (equation 3) based on $\mathbf{s^2_{reg}} = 0.01198$, obtained in fitting equation 2.

Previous investigators analyzed early growth in captive Kemp's ridleys (Caldwell 1962; Klima and McVey 1982; Caillouet and Koi 1985; Caillouet et al. 1986, 1989; Fontaine et al. 1985, 1989; Landry 1989; Wood and Wood 1989) but these studies were based on fewer observations than ours (65,210 observations from 15 year-classes). Our analyses encompassed and added to the data used by Klima and McVey (1982), Caillouet and Koi (1985), Caillouet et

TABLE 2

Estimates of individual weight adjusted for bias (w_{adj}, kg) and straight carapace length (scl, cm) for head-started Kemp's ridleys (*Lepidochelys kempii*) at age 1 and 1.22 yr, for each year-class and combined year-classes.

Year-class	1 yr		1.22 yr	
	w_{adj}, kg	scl, cm	w_{adj}, kg	scl, cm
1978	1.11	18.6	1.83	22.1
1979	1.34	19.9	2.25	23.7
1980	1.52	20.7	2.47	24.5
1981	0.86	17.1	1.48	20.5
1982	1.17	19.0	1.97	22.6
1983	0.56	14.7	0.83	16.9
1984	0.80	16.6	1.27	19.5
1985	2.52	24.6	5.20	31.6
1986	1.86	22.2	3.10	26.5
1987	2.29	23.8	4.51	30.1
1988	1.10	18.6	1.92	22.5
1989	0.64	15.4	1.06	18.3
1990	0.94	17.6	1.66	21.4
1991	0.62	15.3	0.96	17.7
1992	1.22	19.2	2.35	24.0
Combined	1.26	19.5	2.17	23.4

al. (1986, 1989) and Fontaine et al. (1985, 1989).

The trend of logarithmic decline in the residual variance (s^2_{reg}) of the *ln*-linear growth model (equation 1) was probably due to a shift toward sex ratios dominated by one sex (females), improvements in rearing facilities, year-around control of seawater temperature which reduced disease incidence, improved diet, and reduced feeding levels (Fontaine et al. 1985, 1989; Caillouet et al. 1986, 1989; Leong et al. 1989; Caillouet 1995a). Year-classes 1978-1985 in which both sexes were well represented exhibited greater variation in individual w than those in which most individuals were females, suggesting a possible difference in growth characteristics between the sexes.

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